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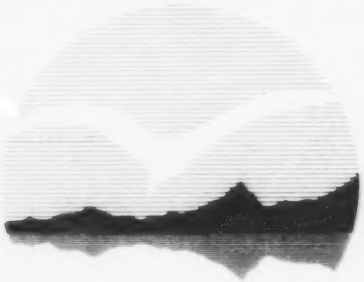

WATER
RESOURCES
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SASKATCHEWAN DISTRICT

INDIRECT METHOD OF DETERMINING DISCHARGE

(SLOPE-AREA SURVEY)

SUGGESTED FIELD & OFFICE PROCEDURES

INDIRECT METHOD OF DETERMINING DISCHARGE

(SLOPE-AREA SURVEY)

SUGGESTED FIELD & OFFICE PROCEDURES

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1.0 INTRODUCTION

Peak flow events often occur unexpectedly and streams may not always peak during daylight hours. These circumstances may prevent a conventional discharge measurement from being made. Other factors which could prevent a conventional discharge measurement from being made include the loss of the usual high water metering facility and poor access to the station since bridge approaches and roads are often washed out.

In the event that a conventional discharge measurement cannot be made for any reason, discharge peaks may be determined by an indirect measurement method. The most common method of indirect measurement is the Slope-Area method.

This report is an outline of one suggested approach that a field crew could use to conduct a Slope-Area survey.

Since the main purpose of this report is to be used as a quick reference guide for the Field Technologist, neither office procedures nor theory are discussed in great detail.

For more detailed procedures, refer to Career Development Program Lesson Package number B-11 "Indirect Determination of Discharge".

2.0 OFFICE PREPARATIONS

The first indication of a peak event usually comes from the news media, by weather reports and reports of flooding. These reports will generally refer to the general area where the event has taken place.

2.1 ISOLATING THE EVENT

The first step is to isolate the area of the peak event by contacting people or agencies in the general area. Some of these contacts may include:

1. Meterological observers
2. Gauge readers
3. Weather office
4. Highways Department
5. Municipal or town offices in the general area
6. Local grain elevator manager
7. Local service stations
8. Local hotel owner
9. Local office of the PFRA
10. Sask Water Corporation
11. Ducks Unlimited office
12. Landowner

A list of possible contacts throughout the province is included in the "Special Events Procedures Manual". The manual also has a section on the availability of equipment and aircraft in each area.

The area of the event may also be determined by interrogating the DCP network and by accessing Telemarks.

2.2 ASSESSING THE EVENT

Once an indication of the event and intensity of the event is determined the next step is to consult a hydrologic network map to determine which gauges are most likely to be affected.

During the assessment stage, it is preferable to send one or two field technologists to the general area with the purpose of assessing the event and reporting back by phone to the office. Based on the assessment of the event, equipment and personnel can be directed to the appropriate sites.

3.0 PRELIMINARY FIELD SURVEY

Once the event has been isolated and initial field reports indicate that conventional measurements cannot be made, plans must be made for conducting a Slope-Area survey. At this time manpower and equipment requirements must be determined and directed to the site.

3.1 SECURING THE STATION

On arrival at the site, the first consideration must be for safety. If the station is equipped with electrical power service, the power should be turned off at its source. Usually, the service pole or transformer installation has a main switch. Disconnecting the electrical power in this manner will prevent the possibility of injury from electrical shock when the gauge shelter is entered.

With the power sources shut off, the shelter should be entered to assess damage and retrieve the record or damaged instrumentation. If the approach to the shelter is submerged, proceed with caution, probing ahead with a computing rod or shovel, since high flows often scour fill material from around the well or shelter. Use caution when entering well-type installations since the trap doors often float up and may remain in an open position even after the stage drops.

Since one of the criteria for conducting a Slope-Area survey is the determination of the peak stage, a careful examination of the gauge must be made to identify high water marks. If the gauge has been flooded, highwater marks are usually easily identified on the walls or counters within the shelter. Remember that highwater marks inside the shelter could be affected by drawdown. If possible, read the manual gauge and retrieve the chart record. If the recorder has been submerged, it is often better to retrieve the chart roll intact without unrolling it. This will minimize damage to the chart. The chart takeup roller may also need to be removed to prevent further damage to a wet chart. An alternate method is to remove the recorder with the chart intact. The chart may be removed from the roller after it has dried.

Measures should be taken to ensure the continued collection of stage record. If the stage is continuing to rise, and it appears that the instrumentation will be submerged, the recorder or other monitoring equipment can be raised by using temporary blocking or by installing a temporary raised shelf. In extreme cases, the recorder can be mounted on the roof of the shelter.

Damaged recorders should be replaced. A temporary replacement may be quickly obtained by removing a recorder from an adjacent area, not affected by the flood.

3.2 CHANNEL SECTION SELECTION

Once the gauge has been secured, plans must be made for carrying out the work necessary to conduct a Slope-Area survey.

One or more of the following criteria should be met when selecting a reach:

i) select a reach in the proximity of the gauge
ii) length of reach should be at least 75 times the mean channel depth and should include the gauge section. Usually a length of 150 to 200 m will be adequate but if there appears to be little slope, a longer reach can be used.
iii) the minimum fall through the reach should be 0.15 metres
iv) channel should be straight and uniform and preferably a contracted well-confined reach, with no sudden break in slope. Rapids or riffles should be avoided.

3.3 STAKING THE HIGHWATER MARKS

Ideally, the best situation would be to stake the water's edge, preferably on both banks in the proximity of the gauge at the time the peak occurs. However, more often, the highwater marks must be staked after the event. In this case, highwater marks will be more easily detected within one or two weeks. After three weeks, fresh vegetal growth may cover or obscure much of the physical evidence.

Two people are required to stake the highwater marks. Both banks should be staked with one person staking each bank, since the change in colouration may be more evident when viewed from the opposite bank.

Evidence of highwater marks may be determined by looking for:

i) a line of small seeds or debris, or
ii) a change in colouration when viewed from the opposite bank
iii) natural filters such as sagebrush will probably contain debris among their branches. Keep in mind that most natural filters, especially the taller bushes and willows were probably bent over by the velocity of the water, and usually spring upright when the flows recede.

The highwater marks may be marked using flagged lath, flagged tree trunks, or by building stone cairns. In all cases, it must be remembered that the marks must be easily found and preserved until a formal survey can be carried out.

3.4 DOCUMENTATION OF THE REACH

Double stakes or crossed lath may be used to mark the ends of the reach. Each stake should be well flagged and any pertinent information such as chainage and date should be written on them. This information will help prevent confusion when the formal survey is carried out at a later date.

Notation and a small sketch in the field notes are useful to document the general layout of the reach. Keep in mind that vegetation will grow in profusion after the recession, and much of the physical evidence of the highwater marks will be lost. Notes should also be made describing the hydraulics of the reach. Several pictures of the reach should be taken since this will prove invaluable when selecting an appropriate roughness coefficient for the discharge calculations.

3.5 MAKING A DISCHARGE MEASUREMENT

A conventional discharge measurement should be made at the earliest opportunity - even a poor measurement is better than none. Continue to make measurements as the stage recedes. Stake the water level on both banks at same cross-sections as the highwater marks were staked. This should be done for all discharge measurements if possible but at the very least for the following:

i) first measurement after the event
ii) first good measurement after the event
iii) at each apparent change of channel roughness.

The purpose for doing this is to provide enough information so that Manning's equation can be worked backwards to determine some of the unknowns. For example:

$$Q = \frac{AR^{2/3}S^{1/2}}{n} \quad \text{(Mannings)}$$

$$Q = AR^{2/3}k \quad \text{where} \quad k = \frac{S^{1/2}}{n}$$

If several measurements are taken, various values of k can be determined and used to estimate a k value at the peak stage. Similarily the equation can be solved for n at various stages. The information discussed above will greatly assist the office computations when trying to determine the average slope and n, particularly in cases where cross-sections have to be sub-divided because of varying n-values, overbank flow, etc. The staked actual water level would help to determine the highwater level.

The staked water levels will be surveyed in at the time of the formal survey.

4.0 FORMAL SURVEY

The survey crew should consist of at least four people: an instrument man, a notekeeper, and two rodmen. A suggested list of equipment appears at the end of this report.

Upon arrival at the site, a reconnaissance of the reach should be made while referring to the preliminary field survey notes. Often several stakes may have to be reset since cattle, etc. may have destroyed them.

The formal survey will consist of the following segments:

1) Selecting cross sections
2) Surveying the cross sections
3) Running a centreline profile
4) Surveying the highwater marks.

4.1 SELECTING THE CROSS SECTIONS

The accuracy of the measurement results will depend largely on the number of cross sections taken. The cross sections should be representative of the reach being surveyed. A minimum of three sections is required, but it is usually better to do four or five since an undesireable cross section may not become evident until the final survey data are being processed. This will later give the option of eliminating one or more of the cross sections which may have given erroneous results.

4.2 SURVEYING THE CROSS SECTIONS

The purpose of this segment is to collect enough information to enable the survey results to be accurately transferred onto a site plan.

Once the cross sections have been selected and marked out with flagged lath and 50 mm x 50 mm (2" X 2") hubs at either end, a suitable base line should be established in order to provide a reference for mapping the survey later. The right and left bank cross section lines and high water marks can be surveyed in with a transit. Distances and angles to each point may be done simultaneously by reading stadia distances and the horizontal vernier or by using a tagline. Elevations and the actual cross sections are usually done by surveyor's level for the sake of simplicity.

All of the land surveying may be done by triangulation alone by measuring the stadia distance to the desired point from two other points thus producing a series of overlapping triangles which may then be transferred to a plan. However, it usually will require less effort if a combination of horizontal angles and stadia distances are used.

In brief, the land survey portion required for mapping may be done with a transit by using a combination of horizontal angles, stadia distances and triangulation.

It will be beneficial to draw sketches in the field book showing the relative position of the cross sections for reference when the mapping is being done.

Field notes should be clear and self explanatory. For example:

Set up on point A_{RB}, sight on A_{LB}, turn angle clockwise to B_{RB}.

Angle $A_{LB}\ A_{RB}\ B_{RB}$ = 97° 30' 10"
Distance $A_{RB}\ A_{LB}$ = 74.5 m
Distance $A_{RB}\ B_{RB}$ = 107.9 m

It is strongly recommended that several pictures be taken during the survey. The pictures will provide invaluable information when the office computations are being done, and may prevent the necessity of an additional trip to the site to clarify some small details.

Levels are normally referenced to the gauge datum, but a bench mark of assumed elevation may be established in the absence of an existing bench mark.

4.3 RUNNING A CENTRELINE PROFILE

A centreline profile is not always required, but may be used to explain possible causes of break in slope which may be more evident during the calculations of discharge.

It is usually not necessary to run a separate centreline profile since this may be plotted from the cross section information. However, if the streambed appears to be irregular between cross sections, a centreline profile may be surveyed using a tape or tagline for determining distance, and a surveyor's level used for determining elevation. Station 0+00 will usually be located at the extreme upstream cross section.

4.4 SURVEYING THE HIGHWATER MARKS

The location and elevation of the identified highwater marks are usually tied in during the transit-tape survey as described in Section 4.2. Be sure to make general notes concerning the composition of banks, main channel, and overflow sections, as this will be invaluable when determining a roughness coefficient.

5.0 OFFICE PROCEDURES

Once the field survey has been completed, the field notes and all other pertinent information must be forwarded to the district office for processing. The following is a suggested sequence of steps which should be followed in order to process the data. For more detailed procedures, refer to the reference material listed at the end of this report.

5.1 NOTE REDUCTION

The field notes must be reduced and checked. Elevations will be determined for each level rod reading. All ground level shots may be reduced to the nearest 0.01 metre.

5.2 PLOTTING DATA AND COMPUTATIONS

1) Select a convenient scale, and plot the cross sections on gridded paper. All cross sections must be clearly labelled.

2) Plot the left bank, right bank, and centreline profiles.

3) From the field notes, draw the site plan showing the relative location of the cross sections, the left and right bank highwater marks, the gauge, the baseline and any other information that was tied in by the survey.

4) Determine the cross-sectional areas for each cross section using a planimeter or the cross sections may be digitized and the PAL computer program used.

5) From the cross sections, calculate the wetted perimeter which is the length of the cross section in contact with the water at the time that the peak stage occurred. The cross sections may have to be divided into several segments; for example, left, right and centre, if it appears that the roughness coefficient is significantly different between the banks and the main channel. In this case, areas and wetted perimeters will have to be determined for each segment.

6) Construct a line of average water level slope on the profile.

7) Using Mannings formula, $Q = 1/n\ AR^{2/3}\ S^{1/2}$, compute the discharge

Where, Q = discharge (m^3/s)
n = Mannings Roughness Coefficient (from Tables)
A = cross-sectional area (m^2)
S = Slope or Energy Grade Line
R = Hydraulic Radius

Note that the calculations of the Slope-Area discharge and the final report is usually done by the Hydrologist who may seek some technical assistance in the calculations, as well as in preparing the final report.

For an example of a recent Slope-Area Survey and Report, refer to:

"Lodge Creek Below McRae Creek at International Boundary (11AB083)
Slope-Area Survey of Sept 25, 1986 Flood Peak"

by Brian Yee
Boundary Waters Engineer
WRB, Regina, August, 1988

WRB Saskatchewan Library Reference: PAM 2073

6.0 RECOMMENDATIONS FOR FIELD COVERAGE OF PEAK EVENTS

Based on direct experience with the September 1986 peak rainstorm event on Lodge and Battle Creeks, some deficiences became evident. Due to the lateness of the season, the event took everyone by surprise which resulted in some initial confusion. No long range contingency plans were in place to cover the late fall event, unlike a spring runoff event where volumes and timing are more predictable, thus enabling more concrete planning to take place.

As a result of this event, the following recommendations are made:

1) A Long Range Contingency Plan for unexpected and peak events must be drawn up. This has already been addressed to some extent by the drafting of a Peak Events Procedures Manual for WRB Saskatchewan.

2) Sediment Coverage: Since the duration of the peak is relatively short, and in most cases will involve several gauges, it may be necessary to establish an additional crew of perhaps two technologists to collect the necessary sediment data. The assistance of a sediment specialist may also be required. A contingency plan should be available for this purpose so that a quick response on short notice could be made. This crew could concentrate on collecting sediment data only, and this should result in good quality sediment data being collected, and at the same time permitting the hydrometric crews to concentrate on metering the peak flows.

3) Involvement of the Engineering Staff: It is recommended that some of the engineering staff be included in the field coverage of the event. They would act as co-ordinators to direct the survey crews to the various sites so that optimum use of helicopters, equipment, and available manpower could be used to the best advantage. There definitely appears to be a need for a co-ordinator, since crews are often isolated from each other, and opportunities to re-schedule the work are rare during each day. In most cases, the only contact between crews will be at the end of the day, when the field coverage is assessed and plans for the following day are made. The co-ordinator could utilize the helicopter during periods when it would be sitting idle. This would enable him to do reconnaissance, take pictures throughout the basin, or make general notes on flooding. A wealth of data could be gathered in this manner with very little additional cost.

The adoption of the preceeding procedures and recommendations should result in better coverage and the optimum use of manpower and equipment during future peak events.

APPENDIX

LIST OF SUGGESTED EQUIPMENT AND MATERIALS

FOR SLOPE-AREA SURVEY

I. MANPOWER

- varies with each survey

maximum crew of four:

i) Party Chief - level notes, directs survey
ii) Instrument man - experienced with transit
iii) Two rodmen

II. EQUIPMENT LIST

1) Vehicles: trucks and boats as needed
2) Level: Wild N-2 model, or automatic level
   Instruments should be checked and adjusted if required
3) Rods: 2 - 4 m rods plus 1 - 5 m rod
4) Transit or Theodolite - for stadia and angles
5) Plumb bob - optional is transit equipped with optical plummet
6) Range poles (optional) - 2 (can use 2 lath fastened together)
7) Hatchets - 2
8) Waders
9) Field book - 2
10) Stakes (50 mm X 50 mm) - 30 per site also 1 bundle of lath
11) Flagging - two colours
12) Camera - wide-angle lens preferrable
13) Tapes, steel or cloth open reel type - 2 (500-100 m)
14) Taglines - 2 (100 m)
15) Miscellaneous - spray paint, nails, etc.

FIELD SURVEY CHECKLIST

MANPOWER AND EQUIPMENT

- Varies with each survey

Maximum Crew of 4
1. Party Chief - Level & notes - directs survey
2. Instrumentman - experienced with transit
3. Rodman) Two rodmen experienced at finding
4. Rodman) high water marks and lines of sight

Equipment List - not comprehensive

	1. VEHICLES:	trucks & boats, as needed 4 X 4 is nice during wet weather
	2. LEVEL:	check adjustments as often as possible - throughout the day with N-2 - at night with non-tilting models
	3. RODS:	2 - light weight Haltofors, 4 m rods plus - 1 - 5 m rod
	4. TRANSIT OR THEODOLITE	- for stadia and angles: - best to use internally reading optical - bubble for telescope is advantageous
	5. PLUMB BOBS:	- minimum of 2 (14 oz. with Gamma Line
	6. TARGETS:	- minimum of 2
	7. HATCHETS:	- 2
	8. MACHETE:	- 2
	9. WADERS:	
	10. RIGHT ANGLE PRISM:	- 1
	11. FIELD BOOKS:	
	12. STAKES:	- 30 per site minimum 50 mm X 50 mm X 600 mm (15/side)
	13. FLAGGING:	- red and green
	14. RANGE POLES:	- can make at site
	15. PAINT & PERMANENT MARKERS:	
	16. HAND RADIOS AND CHEST PACKS WITH BATTERY CHARGERS:	
	17. CAMERA:	- wide angle lens
	18. BACK PACKS:	- 2 or 3
	19. HAND LEVEL:	
	20. TAPES:	- steel or cloth, minimum 2 - open reel preferable
	21. TAG LINE:	- 2 (100 m)
	22. COMPASS:	
	23. RAIN GEAR:	- for instruments, as well i.e. plastic bags
	24. INSECT REPELLENT:	- sunscreen, etc.
	25. LUNCH:	
	26. 30 m-10 mm ROPE:	
	27. SUPPLY OF 5 mm ROPE:	- tie back
	28. OTHER STUFF:	

LIST OF REFERENCES

1. "Lodge Creek Below McRae Creek at International Boundary, Slope-Area Survey of Sep. 25, 1986 Flood Peak", by B. Yee, Boundary Waters Engineer, WRB, Regina, August, 1988. WRB Saskatchewan Library Reference: PAM 2073

2. "Measurement of Peak Discharge by the Slope-Area Method", WRB Saskatchewan Library Reference: SER US Geological Survey, Techniques of Water Resources Investigations, Book 3, Chapter A2

3. "Indirect Determination of Discharge", CDP Lesson Package by A. Glennie, Hydrology Division, WRB, Winnipeg, Manitoba, May, 1989.